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EFFECT OF SOWING PERIOD ON SEED YIELD AND ESSENTIAL OIL COMPOSITION OF CORIANDER (*Coriandrum sativum* L.) IN SOUTH-EAST BULGARIA CONDITION

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Abstract

Coriander (Coriandrum sativum L.) is one of the most important spice and aromatic plants grown worldwide. It is an annual plant, belonging to the Apiaceae family, which is cultivated mainly for its fruits (seeds). The productivity of coriander is influenced by weather conditions, agronomic and genetic factors. In this paper the influence of six sowing periods (October, November, December, February, March and April) on yield and essential oil quality of the coriander cultivar 'Alekseevski' is discussed. The study was carried out during 2015-2018 in south-east Bulgaria on vertisols leached soil type. Field experiments were performed by means of a block method with four replications; experimental field area was 15 m^2. The pre crop of coriander was winter wheat. All the stages of the established technology for coriander growing were followed. The indicators seeds yield (kg ha^{-1}), essential oil content (%), essential oil yield (kg ha^{-1}) and essential oil composition of coriander were determined. The obtained data was statistically processed by the dispersion and correlation analyses methods. The obtained results showed that sowing period in combination with meteorological conditions during the years of the study had a significant influence on productivity of coriander, grown in the study. The highest seeds and essential oil yields (2302 kg ha^{-1} and 26.8 kg ha^{-1}, respectively) in the October sowing period were reported, and the lowest ones (1582 kg ha^{-1} and 11.8 kg ha^{-1}) in the April sowing was recorded. The essential oil content in coriander fruits was lower by the later sowing period. The year of the experiment and sowing period affected essential oil composition.

***Key words**: coriander, sowing period, seed yield, essential oil, essential oil composition.*

INTRODUCTION

Coriander (*Coriandrum sativum* L.) is one of the most important spice and aromatic plants grown in world. It is an annual plant, belonging to the *Apiaceae* family, which is cultivated mainly for its seeds (Delibaltova et al., 2012). The productivity of coriander is determined by genetic traits of cultivars, the environmental factors as well as by the agro-technical practices (Marinov et. al., 2017; Nowak and Szemplinski, 2014). The maximum fruit and essential oil yields are attained only when an appropriate combination of these factors are provided for the plant (Gil et al., 2002; Kassu et al., 2018). Sowing period is some of the major agronomic factors for the vegetative growth and ultimate yield expressions. Any early or lateness in sowing may hamper the growth, yield as well as quality of the coriander (Sharangi and Roychowdhury, 2014). According to the investigations of Bhadkariya et al. (2007) the sowing period have the effect on plant height, number of branches per plant, number of umbel per plant, number of the seeds per umbel and seeds yield. The sowing period affected yield and essential oil quality of coriander as well as on the seeds yield (Zheljazkov et al., 2008). Gujar et al. (2005) reported that the maximum values were recorded for all the characters when the seeds were sown on 10^{th} of October. Yildirim and Gok (2012) found that the highest essential oil ratio was obtained as 0.5% from May 20^{th} sowing period. The essential oil average yields changed from 0.09-0.116 l ha^{-1} and Linalool which essential oil component ratio was changed from 68.3-74.8%. Gamma terpinen ratio was changed from 7-8%. The highest gamma terpinen ratio was obtained as 8.8% from April the 20^{th} sowing period. Because of obtaining the highest fruit yield, Moosavi (2012) recommended to sow the coriander on March the 30^{th}. A field trail performed in Iran (Ghobadi and Ghobadi, 2012) showed that at late sowing period the coriander produced satisfactory seed, essential and oil yields. Carrubba et al. (2006) reported that the most productive sowing period was December, and sowing after this period resulted in lower yields. Tanchev (2011) investigated the effect of sowing period on seed yield of coriander of Strandhja region (Bulgaria) and reported those highest yields were formed by sowing in autumn. The obtained yield was 84% higher than those of springs sowing. In this regard, for coriander, comprehensive information is very much scanty and very little research is conducted in Bulgaria to study the effect of sowing period on seed yield and essential oil of this crop.

The aim of the study is to determine the effect of specific climatic factors of year and sowing period as well as their interaction on yield, the seed oil content and the oil chemical composition in coriander seeds.

MATERIALS AND METHODS

Field trials were carried out in the period of 2015-2018 in the region of Elhovo town, South-East Bulgaria. The study was performed by means of a block method with four replications; experimental field area - 15 m^2. The soil type is vertisols leached. The pre crop was winter wheat. The studied coriander cultivar was 'Alekseevski'. The crop was sown in six different periods - October, November, December, February, March and April. The study was carried out by the following practices: soil cultivation - ploughing of the stubble in July and August at a depth of 20-22 cm, twice pre-sowing cultivation with harrowing, the last being at a depth of 5-6 cm. The fertilizer was introduced at the time of sowing of di-ammonium phosphate (P-N 48-18) at a rate of 200 kg ha^{-1}. The sowing between row distances were 12-15 cm and a seed rate was 250 germinating seeds per m^2 at a depth of 3-4 cm. Weeds were controlled by treatment with the herbicide Linurex 45 SC – 2.00 l ha^{-1}, applied after sowing, before germination of the crop. At "rosette" stage dressing with 100 kg ha^{-1} N was applied. Harvesting was done at full crop maturity. The seed yield is determined with standard grain moisture of 9%. The indicators seeds yield (kg ha^{-1}), essential oil content (%), essential oil yield (kg ha^{-1}) and essential oil composition of coriander were determined.

The essential oil from coriander dried seeds was extracted by distillation using a Clevenger collector apparatus. Compositions of the essential oil were determined by Gas Chromatography-Mass Spectrometry (GC/MS) analysis.

The obtained data for the values of the all indices were statistically processed by the method of dispersion and correlation analyses.

The major climatic factors determining the productivity and quality of coriander are temperature and rainfall, their combination and distribution throughout the vegetation season (Dyulgerov and Dyulgerova, 2016). Comparing the values of the average monthly temperatures during the years of the study showed that they were very close in all the three years and they were higher than those measured for a long period of time, with no significant deviations from the coriander requirements (Figure 1). The years of the study (2015-2018) differed significantly in the amount and distribution of rainfall during vegetation (Figure 2). Its amount in 2015-2016 experimental year was 433.2 mm and those values were very close to the values reported for a long period of time (414 mm), which determined the first year of the experiment as good for the plants. The lowest amount of precipitation was reported in 2017 economic year - 328.9 mm i.e. 85 mm little than the amount measured for a long period of time. That year was characterized by uneven distribution of rainfall, which was not enough to meet the plant requirements for water at the critical stages. In April-June at the stages of buttoning, flowering and fruit setting, the amount of rainfall was 108.6 mm versus 138 mm for a multiple-year period, i.e. about 30 mm less, that determined the second experimental year as less favorable for the productivity of coriander. The last year of the study (2017-2018) was characterized by the greatest amount of rainfall during the vegetation season - 538.0 mm and exceeded the values for the period 1961-1991 by 124.0 mm. Precipitation was evenly distributed during vegetation and in a combination with the reported temperature values, it was considered to be the most favorable for coriander cultivation of the experimental years.

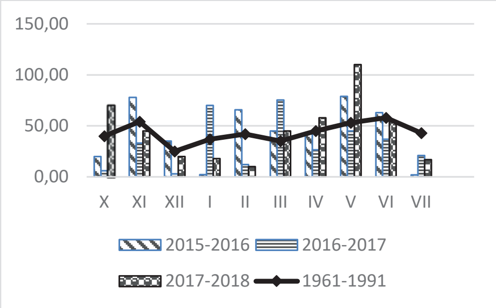

Figure 1. Rainfall, mm

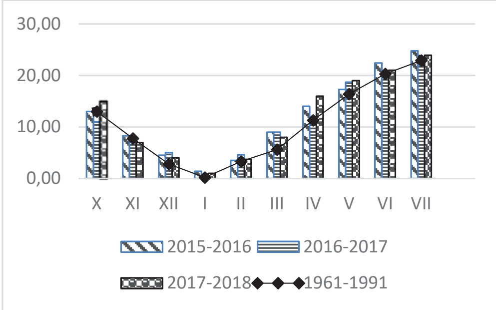

Figure 2. Average monthly air temperature, ^{0}C

RESULTS AND DISCUSSIONS

The yields of coriander seeds during the experiment varied depending on the climatic conditions throughout the years and the sowing period (Table 1). In years with the rainfalls reaching 433.2 (2015-2016) and 538.0 mm (2017-2018) the seed yields were 2041 and 2183 kg ha^{-1}, respectively, which was 30.0 and 38.9 % higher than in the period of 2016-2017. During the first experimental year, the highest statistically significant yield was obtained from October sowing - 2384 kg ha^{-1}, followed by November (2142 kg ha^{-1}), and the lowest - from April sowing (1960 kg ha^{-1}).

Table 1. Seeds yield, kg ha^{-1}

Sowing time	Years of study			Average for the period kg ha^{-1}
	2015-2016	2016-2017	2017-2018	
October	2384^e	1963^f	2560^f	2302
November	2142^d	1840^e	2345^e	2109
December	2100^c	1726^d	2230^d	2017
February	2065^c	1400^c	2110^c	1858
March	1863^b	1325^b	1980^b	1723
April	1690^a	1180^a	1875^a	1582
Mean for year	2041	1572	2183	

*Means within columns followed by different lowercase letters are significantly different (P<0.05) according to the LSD test.

The insufficient rainfall during the vegetation season of 2016-2017, especially during the stages of coriander buttoning, flowering and fruit setting, was the reason for the low seed yields, which varied from 1180 to 1963 kg ha^{-1} for the studied sowing period. In that year, coriander sown in November surpassed in yields – December, February and March sowing by 6.6, 23.4 and 30.2%, respectively, but fall behind October sowing by 6.7%, the values are being significant. The more favorable climatic factors in 2017-2018 preconditioned the formation of a higher seed yield than in the other two experimental years. During the three experimental years, the highest yield of seeds formed by October sowing - 2560 kg ha^{-1} and it exceeded the November, December, February and March sowing by 215, 330, 450 and 580 kg ha^{-1}, respectively, the differences were statistically significant.

The lowest seed yield was formed after April sowing, the values being 36.5% lower than the yield from October, 25.1% lower than November, 18.9% lower than December, 12.5% lower than February and 5.6% lower than March sowings, which was statistically proved. This result corresponds with Bhadkariya et al. (2007), Ghobadi and Gobadi (2012), Moosavi (2012) and Tanchev (2011), who reported that earlier sowing of coriander led to the highest seed yields. The dispersion analysis about the effect of the factors Sowing time and Year, as well as their interaction, on the seed yield, showed a significant influence of the factors on the changes of the characteristic and statistically insignificant effect of the interaction between them (Table 2).

Table 2. Analysis of variance ANOVA

Source of Variation	Sum of Square	Df	Mean Square	F	P-value	F crit
Year**	4904087	2	2452044	23695.48	0.00	3.168246
Sowing time**	4175610	5	835122	8070.255	0.00	2.38607
Interaction**	190198.2	10	19019.82	183.7993	0.00	2.011181
Within	5588	54	103.4815			

*F-test significant at P<0.05; **F-test significant at P<0.01; ns non-significant

The content of essential oil in coriander seeds was affected by both the year and the sowing period (Figure 3). In 2016, when the average air temperature during the period of fruit maturation was 24.8^{0}C and the rainfall equalled - 2 mm., depending on sowing period, the coriander seeds had oil content from 0.87 to 1.23%, which was higher than in 2017, when the average daily temperature was 22.0^{0}C and the rainfall was 21 mm.

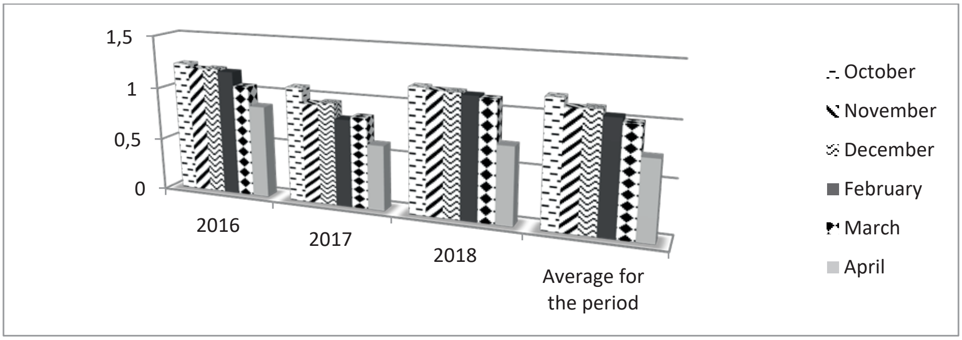

Figure 3. Effect of sowing time on essential oil content, %

The content of oil in coriander seeds ranged from 0.61 to 1.08%. In the other years of the experiment (2018), that characteristic was from 0.72 to 1.17%. This is also confirmed by an experiment conducted by Zawiślak (2011) in Poland, where the concentration of oil in coriander fruits was distinctly different in two consecutive years (1.87% in 2007 and 2.33% in 2006). On average for the period of 2015-2018, the highest essential oil content of 1.17% was obtained when coriander was sown in October. Sowing after that time the values of this indicator decreased and ranged from 0.73 to 1.09%. The sowing period in this experiment, similarly to the obtained data from trials conducted by Moosavi et al. (2012) as well as Zheljazkov et al. (2008) induce differences in the content of essential oil in coriander seeds. In Iran and Canada, seeds from an early date of sowing contained more essential oil than seeds from plant sown latter.

The results of the dispersion analysis about the effect of the factors Sowing time and Year, as well as their interaction on the indicator seed yield are presented in Table 3. The results showed a statistically significant effect of the studied factors and insignificance of their interaction.

Table 3. Analysis of variance ANOVA

Source of Variation	Sum of Square	df	Mean Square	F	P-value	F crit
Year*	0.847136	2	0.423568	40.7277	0.00	3.168246
Sowing time*	1.373294	5	0.274659	26.40951	0.00	2.38607
Interactions^{ns}	0.108564	10	0.010856	1.043884	0.42	2.011181
Within	0.5616	54	0.0104			

*F-test significant at P<0.05; **F-test significant at P<0.01; ns non-significant

The essential oil yield of coriander was affected significantly by different sowing periods (Figure 4). The results confirm that the values of that indicator depended to a sowing period, ranging from 14.7 to 29.3 kg ha^{-1}; 7.2-21.2 kg ha^{-1} and 13.5-29.9 kg ha^{-1} in 2016, 2017 and 2018, respectively. The highest oil yield, on average for the period of the study, was obtained from October sowing period (26.8 kg ha^{-1}) surpassing by 15.5%, 19.1%, 34.7 and 52.3% the November sowing period, December, February and March, and the lowest yield was obtained from April sowing period - 11.5 kg ha^{-1}. The fact that coriander tends to essential lower oil yield when sown later has also been reported by other researchers (Zheljazkov et al., 2008; Özel et al., 2009; Moosavi et al., 2012).

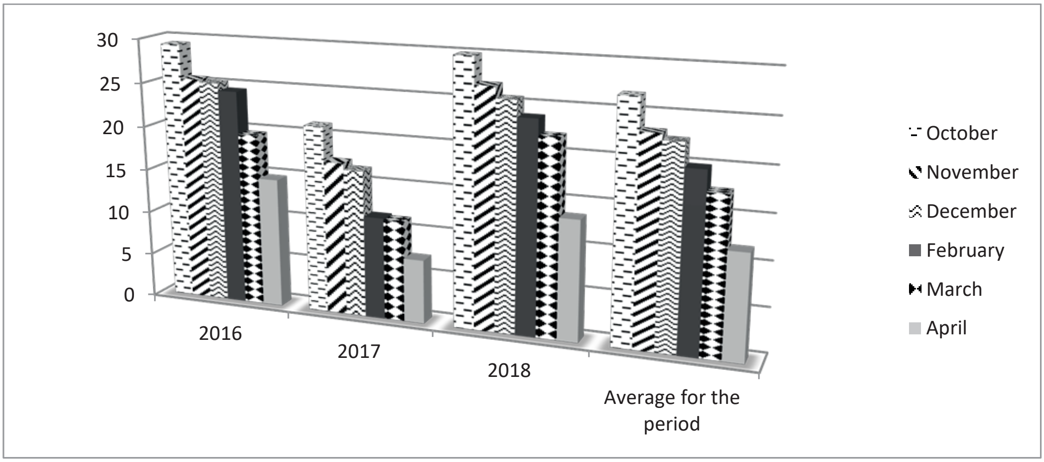

Figure 4. Effect of sowing period on essential oil yield, kg ha^{-1}

The results of the dispersion analysis about the influence of the factors and their interaction on the essential oil yield showed clear statistically significant variations, and the interaction between the two factors was statistically insignificant (Table 4).

Table 4. Analysis of variance ANOVA

Source of Variation	Sum of Square	df	Mean Square	F	P-value	F crit
Year*	1230.163	2	615.0817	69.94606	0.00	3.168246
Sowing time*	1346.758	5	269.3516	30.63021	0.00	2.38607
Interactions^{ns}	147.53	10	14.753	1.677686	0.11	2.011181
Within	474.8575	54	8.793657			

*F-test significant at P<0.05; **F-test significant at P<0.01; ns - non-significant

The composition of coriander oil, in which a profile of 12 chemical compounds were determined, was dominated by linalool (Table 5). This is the major constituent of essential oil in coriander seeds, responsible for their typical aroma (Carrubba et al., 2006). In the present experiment the concentration of linalool depending on the sowing time range from 61.0 to 67.0% in 2016, 58.0-65.0 in 2017 and 63.0-68.0% in 2018. Many authors report similar percentages of linalool in coriander essential oil. For example, Nowak and Szemplinski (2014) determined the concentration of linalool in coriander oil at 65.3 and 67.1% from fruits in Olsztyn in two years. In Poland, the percentage determined by Zawiślak (2011) ranged from 69.9 to 72.5%, while in Canada the results obtained by Zheljazkov et al. (2008) revealed from 64.0 to 84.6% of linalool in coriander essential oil. Delayed sowing period decreased the content of linalool in coriander oil (Zheljazkov et al., 2008). Other dominant component of coriander essential oil were camphor, α-pinene, γ-terpinene, ρ-cymene, limonene, α-terpineol, geranyl acetate, geraniol, camphene, sabinene and myrcene. The concentration of camphor, α-pinene, ρ-cymene, α-terpineol, geranyl acetate and myrcene was greater in seed oil from the October sowing compared to the other sowing periods in the experiment. The sowing time influences the essential oil composition of the coriander seeds with the exception of the limonene, sabinene γ-terpinene and camphene. The year with specific climatic conditions has a strong influence on the content of this composition, with the exception of sabinene. The strongest is the impact of the year on the content of camphor.

Table 5. Essential oil composition of coriander, %

Constituents	Years of study	Sowing time						Significance	
		October	November	December	February	March	April	Year	Sowing time
α-pinene	2015-2016	6.3	5.3	5.5	5.5	4.5	4.2	*	*
	2016-2017	7.0	6.2	6.0	6.1	5.3	4.5		
	2017-2018	6.0	5.6	5.4	4.7	4.1	3.2		
ρ-cymen	2015-2016	1.4	1.4	1.1	1.3	1.0	-	*	*
	2016-2017	1.6	1.6	1.3	1.2	1.1	-		
	2017-2018	1.3	1.1	1.0	1.0	0.8	-		
α terpineol	2015-2016	0.6	0.6	0.5	0.5	-	-	*	*
	2016-2017	0.4	0.4	0.3	-	-	-		
	2017-2018	0.7	0.6	0.4	0.5	0.48	-		
Limonene	2015-2016	1.5	1.4	1.4	1.5	1.3	1.0	*	ns
	2016-2017	2.0	2.5	2.8	2.8	2.8	3.4		
	2017-2018	1.6	1.5	1.5	1.6	1.6	2.1		
Myrcene	2015-2016	1.1	1.0	0.9	0.8	0.5	0.5	*	*
	2016-2017	0.8	0.8	0.5	0.3	0.2	-		
	2017-2018	1.2	1.1	1.2	0.9	0.9	0.5		
Geranyl acetate	2015-2016	2.6	2.4	1.9	1.7	1.6	1.6	*	*
	2016-2017	1.7	1.3	1.1	-	-	-		
	2017-2018	2.6	2.5	2.0	2.1	1.3	1.2		
Sabinene	2015-2016	0.5	0.5	0.3	0.18	0.15	0.15	ns	ns
	2016-2017	0.4	0.2	0.4	0.45	0.48	0.48		
	2017-2018	0.6	0.6	0.4	0.2	0.1	0.16		
ϒ- terpinene	2015-2016	6.5	6.5	6.3	6.0	6.2	6.0	*	ns
	2016-2017	5.8	5.9	5.3	5.2	5.0	5.0		
	2017-2018	7.1	7.2	7.0	7.5	6.1	5.3		
Linalool	2015-2016	67.0	65.0	63.0	63.0	62.0	61.0	*	*
	2016-2017	65.0	63.0	61.0	60.0	59.0	58.0		
	2017-2018	68.0	66.0	64.0	64.0	64.0	63.0		
Camphor	2015-2016	6.9	6.6	5.8	5.1	4.5	4.1	**	*
	2016-2017	8.4	8.0	7.6	6.7	6.5	6.3		
	2017-2018	6.0	5.6	5.1	4.2	4.0	4.0		
Geraniol	2015-2016	2.0	2.1	1.9	1.7	1.5	1.4	*	*
	2016-2017	1.3	2.0	1.9	1.15	1.30	1.35		
	2017-2018	2.5	2.3	2.0	2.1	1.9	1.7		
Camphene	2015-2016	0.61	0.61	0.65	0.60	0.50	0.45	*	ns
	2016-2017	0.87	0.91	1.20	1.15	1.30	1.32		
	2017-2018	0.52	0.50	0.48	0.47	0.42	0.40		

*F-test significant at P<0.05; **F-test significant at P<0.01; ns - non-significant

The results of correlation analysis between the seed yield, the essential oil content and the oil yield as well as the major components of coriander essential oils, are presented in Table 7. The results show that the highest correlation coefficients obtained from the correlation between essential oil yield and seed yield (0.963), essential oil yield and essential oil content (0.954), myrcene and seed yield (0.958), geranyl acetate and seed yield (0.953), linalool and seed yield (0.957), essential oil yield and myrcene (0.952), essential oil yield and linalool (0.907), essential oil yield and geranyl acetate (0.926), geranyl acetate and myrcene (0.904), linalool and myrcene (0.923) as well as between geranyl acetate and linalool (0.902).

Table 7. Values of the coefficient of correlation

	seed yield	essential oil	essent.oil yield	α-pinene	ρ-cymen	α-terpineol	Limonene	Myrcene	Geranyl acetate	Sabinene	ϒ-terpinene	Linalool	Camphor	Geraniol	Camphene
seed yield	1														
essential oil	0,855*	1													
essent.oil yield	0,963**	0,954**	1												
α-pinene	0,231	0,398	0,336	1											
ρ-cymen	0,415	0,649*	0,536	0,841*	1										
α - terpineol	0,810*	0,778*	0,844*	0,570	0,631	1									
Limonene	-0,737	-0,726	-0,735	0,144	-0,076	-0,404	1								
Myrcene	0,959**	0,880*	0,952**	0,312	0,494	0,814*	-0,696	1							
Geranyl acetate	0,953**	0,832*	0,926**	0,184	0,340	0,800*	-0,812	0,904**	1						
Sabinene	0,146	0,107	0,193	0,557	0,319	0,435	0,265	0,152	0,106	1					
ϒ- terpinene	0,850*	0,777*	0,851*	0,106	0,284	0,713*	-0,729	0,856*	0,864*	0,109	1				
Linalool	0,957**	0,784*	0,907**	0,312	0,460	0,780*	-0,637	0,923**	0,902**	0,223	0,771*	1			
Camphor	-0,130	-0,011	-0,060	0,840*	0,631*	0,299	0,510	-0,050	-0,136	0,541	-0,296	0,008	1		
Geraniol	0,819*	0,631*	0,768*	0,105	0,304	0,764*	-0,419	0,807*	0,766*	0,236	0,767*	0,757*	-0,087	1	
Camphene	-0,744	-0,556	-0,652	0,372	0,119	-0,304	0,897	-0,682	-0,760	0,379	-0,717	-0,667	0,672	-0,510	1

*significant at 5% probability level; **significant at 1% probability level

High positive correlation coefficients were obtained from the correlation between essential oil content and seed yield (0.855), α-terpineol and seed yield (0.810), ϒ- terpinene and seed yield (0.850), geraniol and seed yield (0.819), essential oil content and myrcene (0.879), essential oil content and geranyl acetate (0.832), ϒ- terpinene and essential oil yield (0.844), α-pinene and ρ-cymen (0.841), α-pinene and camphor (0.841), α-terpineol and myrcene (0.814), geranyl acetate and ϒ-terpinene (0.864).

CONCLUSIONS

In general, the obtained results showed that the sowing period in combination with meteorological conditions during the years of the study had a significant influence on coriander seed yield, essential oil content and oil yield, grown in the region of the town Elhovo, South-East Bulgaria.

The highest seed and essential oil yields (of 2302 kg ha^{-1} and 26,8 kg ha^{-1}) were reported in the October sowing and the lowest one - of 1582 kg ha^{-1} and 11.8 kg ha^{-1} in the April sowing. The content of essential oil was lower for the later sowing periods.

The years of the experiment and sowing period affected essential oil composition such as linalool, camphor, α-pinene, ρ-cymene, α-terpineol, geranyl acetate, geraniol and myrcene.

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